Lesson One

General Biology

1.1 Intensive Reading

Conceptual Foundations of the Biological Sciences

All too often biology education appears to be defined by trivia [1] — an impression that can alienate [2] students from what is an inherently highly personal and intellectually fascinating subject. How is such a situation possible? It stems from common practices that include the following: 1) not seriously considering biology's historical and intellectual foundations; 2) underestimating the need for students to come to biology with a robust grounding in physicochemical [3] principles (thermodynamics [4], molecular structure and formation, reaction dynamics, and systems thinking); 3) a failure to acknowledge the deeply nonintuitive [5] aspects of biological theory; and 4) a failure to think deeply, or perhaps better put, systematically, about the principles that define biological systems. The typical biology curriculum can be viewed as a fragmented collection of facts and idiosyncratic [6] observations, as opposed to overarching [7] principles that are the equivalent to the laws of physics. This approach leaves students in a conceptual vacuum, trying to memorize facts such as the stages of meiosis [8], the steps in the Krebs cycle [9], the components of the electron transport chain [10], the various lipids in membranes, the components of cellular adhesion junctions, and the posttranslational modifications [11] of histones, *etc.* After some decades of teaching and research, including research into, and reflection upon, student thinking, it appears that there are three pillars upon which all of the biological sciences are based: evolutionary thinking, molecular foundations, and network behavior. Something of a similar exercise (but focused on research rather than teaching) has been carried out by the National Academy of Sciences; its primary emphasis was on the modular and network organization of living systems.

Evolutionary Thinking

Honored more in being trivialized than built into the heart of biology curricula, an evolutionary perspective is essential to understanding biological systems. At the cellular and molecular level, we identify two pillars upon which evolutionary theory rests: the cell theory and an understanding of how information is captured through mutational variation [12] and selection. The cell theory implies continuous descent; biological processes do not begin *de novo* [13] but rather unfold within this living context. Cellular adaptation and differentiation provide a loose model for one type of unfolding (evolutionary) change, while cellular interactions underlie the behavior of organisms, organ systems, and ecological communities. Biological information theory is based on the recognition that molecular level "noise" (*i. e.*, mutations in the genetic material, DNA, and genetic drift [14]) provide the raw variation from which natural selection, as proposed by Darwin and Wallace, creates information. It is important to recognize that Darwin and Wallace formed their evolutionary theory without an understanding of how variations arise, and that this ignorance posed a major hurdle to its acceptance. Over the last 100 years, studies in genetics and molecular biology have resolved this issue. At the same time, a growing recognition of the high levels of genomic dynamics [15], including gene duplication and the role of nonadaptive variation suggests that there is a deep and constantly refilling reservoir of genetic variation. Moreover, the universe of genetic variations can be characterized with respect to their phenotypic effects [16] using the coherent system of morphs [17].

Molecular Foundations

It is possible to understand genetics from a completely abstract and logical perspective, that is, without knowing how allelic variation [18] arises, how information is encoded, or how such variation modifies or generates traits. However, without a molecular level understanding biological systems are quite mysterious. What is central to such a molecular level understanding? It certainly includes how atoms combine into molecules and how molecules behave, which implies an understanding of the factors that influence their shape, stability, interactions with other molecules, and reactivity. Such an understanding is based on physicochemical principles. Unfortunately, most students have not mastered these ideas before they take biology. The cell, as the basic living unit: 1) is a nonequilibrium system [19] based on coupled chemical reactions; 2) its structure and the structures of the macromolecules [20] from which it is composed are determined, to a first level approximation, by spontaneous entropic effects [21] arising from interactions with water; and 3) aside from the electric fields and ion gradients [22] associated with certain membranes, such as those in mitochondria [23], muscle, and neurons [24], all interactions within cells are driven by molecular level interactions and entropic (hydrophobic hiding [25]) effects. Moreover, molecular stability, the interactions between molecules, and molecular movement within the cell are driven or influenced by the random thermal jostling [26] of molecules. An understanding of thermal motion as the source of energy driving chemical reactions, together with the importance of reaction coupling, would seem to require, at a minimum, a basic (that is, nonmathematical) understanding of energy transfer, molecular movement, Maxwell-Boltzmann distributions [27], and Le Chatelier's principle [28].

That order can arise spontaneously at the molecular level is a critical revelation. Understanding such processes, though difficult because they are counterintuitive [29], would do much to disarm a broad range of creationist disinformation [30] and dispel students' inherent (and justified) confusion. At the same time, it is clear that such molecular level insights are not likely to be delivered efficiently solely within the context of the biology classroom; they depend upon a robust and facile understanding of physicochemical principles. Yet, all too often, the physics taught to students ignores the molecular level behaviors that are relevant to biological systems, and by the same token chemistry instruction often fails to bring students to the level of conceptual confidence needed to understand the molecular behaviors relevant to biological systems. While chemists may blame biologists for the idea that breaking the terminal phosphodiester bond [31] in adenosine triphosphate [32] releases energy, it is clear that students often leave their chemistry courses without understanding that bond breaking always requires energy, while energy is released upon bond formation. The solution appears to involve an approach based on systems thinking, that is, an explicit consideration of all the bonds broken and formed during a reaction or reaction system. A similar system perspective is required to fully grasp the logic and inevitability of entropy-driven processes [33].

Network Behavior

Thinking about systems leads naturally to an appreciation that all biological systems are dependent upon network behavior [34]. To understand network behavior, we must explicitly identify the network's components, their properties, interactions, and dynamics, and consider analytically the effects of perturbations, that is, whether the network is stable, adaptive, or evolving. Evolving networks characterize embryonic development [35], immunological responses, neuronal activity (thinking and memory), disease origin, progression and cure, and ecological stasis and succession [36]. A student's ability to design a molecular system that behaves like the bacterial *lac* operon or, at the cellular level, determines whether a cell differentiates [37], divides, or dies, is probably more useful in consolidating learning than is the memorization of gene and protein names. In short, students should not "talk the talk" [38]; they must be able to "walk the walk" [39]. Such skills require an accurate appreciation of molecular level function and dynamics and involve analysis and modeling, which will require "making room" in the curriculum for students to master these skills. Such an approach would also enable students to experience for themselves how biological systems work and how their complexity is built from understandable elements. In that light, we find that senior level molecular biology students have serious difficulties generating analytic representations of concepts they might well be assumed to know.

The key to generating a more effective biological curriculum is to suppress the tendency to be generously inclusive (which often results in a preoccupation [40] with trivia) and to concentrate on foundational knowledge and useful skills. These foundational concepts and skills are, in fact, difficult and require serious immersion and practice to master. Holding students to higher performance (rather than memorization) standards, that is, by assessing their ability to carry out real tasks, is critical to making science real, rather than superficial and needlessly obtuse, for the majority of students. Whether this increases the number of students pursuing a career in biology is not as important as the demystification of science, particularly given current problems in fully employing the scientists we already produce and the widespread confusion amid the public of how science works and what it implies in terms of public policy and personal decisions.

Abstracted and adapted from *Thinking about the Conceptual Foundations of Biological Sciences* by Michael W. Klymkowsky. CBE-Life Life Sciences Education, 2010, 9(4): 405-407.

Notes

[1]trivia（琐事，细枝末节）: something of small importance.

[2]alienate（使疏远，离间）: make withdrawn or isolated or emotionally dissociated.

[3]physicochemical（物理化学的）: relating to physical chemistry.

[4]thermodynamics（热力学）: the branch of physics concerned with the conversion of different forms of energy.

[5]nonintuitive（非直觉的）: not spontaneously derived from natural tendency.

[6]idiosyncratic（特质的，特殊的）: peculiar to the individual.

[7]overarching（支配一切的）: dominating all other things.

[8]meiosis（减数分裂）: cell division that produces reproductive cells in sexually reproducing organisms.

[9]Krebs cycle（柠檬酸循环）: a cyclic pathway in mitochondrion leading to the catabolism of acetyl compounds.

[10]electron transport chain（电子传递链）: a series of electron carriers in the electron transport system.

[11]posttranslational modification（翻译后修饰）: a process in eukaryotes in which primary transcript RNA is converted into mature RNA.

[12]variation（变异）: the act or process of being altered or changed.

[13]*de novo*（从头开始）: restart from the beginning.

[14]genetic drift（遗传漂移）: the change in the frequency of a gene variant (allele) in a population due to random sampling.

[15]genomic dynamics（基因组动力学）: science elucidating the molecular mechanisms and evolutionary processes that shape the structure and function of genes and genomes.

[16]phenotypic effects（表型效应）: organism's observable characteristics or traits.

[17]morph（形态变种）: hereditary morphological mutants.

[18]allelic variation（等位基因突变）: mutation of genes at a particular locus on a chromosome.

[19]nonequilibrium system（非平衡系统）: systems that are not in thermodynamic equilibrium.

[20]macromolecules（大分子）: large complex molecules or biopolymers (nucleic acids, proteins, carbohydrates, and lipids).

[21] entropic effects (熵效应): spontaneous reactions towards the direction of undecided increase in entropy.

[22] ion gradients (离子梯度): a concentration gradient of ions, also an electrochemical potential gradient of ions across membranes.

[23] mitochondrion (线粒体): an organelle containing enzymes responsible for producing energy. mitochondria (*pl.*).

[24] neuron(神经元): a cell that is specialized to conduct nerve impulses.

[25] hydrophobic hiding(疏水性内隐): one of characteristics of bio-macromolecules: the hydrophobic groups tend to automatically locate inside.

[26] thermal jostling (热力学运动): thermal motion.

[27] Maxwell-Boltzmann distribution: 麦克斯韦-玻尔兹曼分布.

[28] Le Chatelier's principle: 勒·夏特列原理.

[29] counterintuitive (违反直觉的): contrary to what common sense would suggest.

[30] creationist disinformation (创始论者的误解): misunderstanding hold by creationist.

[31] phosphodiester bond(磷酸二酯键): a diester bond formed by one phosphate group with two hydroxyl groups.

[32] adenosine triphosphate(三磷酸腺苷): a nucleotide derived from adenosine that occurs in tissue, the major source of energy for cellular reactions.

[33] entropy-driven processes (熵驱动过程): the processes promoted by the change of entropy.

[34] network behavior (生物的网络行为): biological behavior in a complex interactive network.

[35] embryonic development (胚胎发育): process with growth and differentiation of cells, and forming of organisms derived from a zygote.

[36] ecological stasis and succession (生态瘀与生态演替): the stable or changing state of a community in ecological evolution.

[37] cell differentiation (细胞分化): process of cells becoming different structure and function.

[38] talk the talk (说说而已): actionless talk about doing something.

[39] walk the walk (说做就做，付诸行动): immediately act after talking about doing something.

[40] preoccupation(全神贯注，当务之急): an idea that preoccupies the mind and holds the attention, the mental state of being preoccupied by something.

Reading Comprehension

Ⅰ Answer the Following Questions Based on the Information Given in the Text

1. What are the conceptual foundations of the biological sciences?
2. What is the Klymkowsky's view on the evolution at the cellular and molecular level? How do you think about Darwin and Wallace's evolutionary theory?

3. Why did the author say biological systems were quite mysterious without a molecular understanding?
4. How to understand network behavior? What are the keys for students to master foundational knowledge and useful skills about biology?

Ⅱ Multiple Choice Questions

1. What was mainly discussed in this passage? ( )
   A: How to develop biology education.
   B: The conceptual foundations of the biological sciences.
   C: Biological systems skills.
   D: The evolutionary theory.
2. Who is the pioneer of evolutionary theory? ( )
   A: J. B. Watson and Charles Darwin.   B: Charles Darwin and Decartes.
   C: Charles Darwin and A. R. Wallace.   D: Decartes and J. B. Watson.
3. What is probably more useful for students' consolidating learning? ( )
   A: Learning the conceptual foundations of biology.
   B: Memorizing of gene and protein names.
   C: Understanding network behavior.
   D: Trying to design a system at molecular level.
4. What is the classical paper of the Darwin? ( )
   A: *The Misbehavior of Organisms*.   B: *On the Origin of the Species*.
   C: *The Descent of Man*.   D: *The Behavior of Organisms*.
5. What drive the interactions within cells? ( )
   A: Molecular level interactions and entropic effects.   B: Molecular movement.
   C: The random thermal jostling of molecules.   D: Membranes movement.

Ⅲ True or False Questions

1. The typical biology curriculum should be changed because it left students in a conceptual vacuum, trying to memorize facts. ( )
2. Something of teaching exercise has been carried out on the modular and network organization of living systems by the National Academy of Sciences. ( )
3. In this paper, the author believed that an evolutionary perspective was essential to understanding biological systems as same as Dobzhansky's. ( )
4. There are two pillars upon which evolutionary theory rests: the cell theory and biological information theory. ( )
5. Darwin and Wallace provided the raw variation from natural selection and formed their evolutionary theory without an understanding of how variations arise. ( )
6. Students have had some ideas of a molecular level understanding already before they take biological courses. ( )
7. Biologists believe that bond breaking always requires energy, while energy is released upon bond formation as same as chemists. ( )

8. There are four components of network behavior. (   )
9. Good memorization is critical to making science real, rather than superficial and needlessly obtuse. (   )
10. Students with senior level in molecular biology have few difficulties generating analytic representations of concepts. (   )

Answers

Ⅰ Answer the Following Questions Based on the Information Given in the Text

1. There are three pillars upon which all of the biological sciences are based: evolutionary thinking, molecular foundations, and network behavior.
2. At the cellular and molecular level, Klymkowsky identified two pillars upon which evolutionary theory rests: the cell theory and an understanding of how information was captured through mutational variation and selection. Darwin and Wallace formed their evolutionary theory without an understanding of how variations arise, and that this ignorance posed a major hurdle to its acceptance.
3. Because a molecular level understanding biological systems included how atoms combine into molecules and how molecules behave, which implied an understanding of the factors that influenced their shape, stability, interactions with other molecules, and reactivity.
4. To understand network behavior, students must explicitly identify the network's components, their properties, interactions, and dynamics, and consider analytically the effects of perturbations. To master these skills, students must go beyond "talk the talk", they must be able to "walk the walk." Such skills require an accurate appreciation of molecular level function and dynamics and involve analysis and modeling, which will require "making room" in the curriculum for students.

Ⅱ Multiple Choice Questions

1. B. 2. C. 3. D. 4. B. 5. A.

Ⅲ True or False Questions

1. T. 2. F. 3. T. 4. T. 5. T. 6. F. 7. F. 8. T. 9. F. 10. F.

1.2 Extensive Reading

Plants and Arthropods: Friends or Foes?

Arthropods（节肢动物）, the largest animal phylum, make up perhaps 80% of known animal species and include insects（昆虫纲）, arachnids（蛛形纲）, and crustaceans（甲壳纲）. The interactions between arthropods and plants are diverse and complex but can be simplified into a basic conflict and two uneasy alliances. The basic conflict is that plants are the most abundant terrestrial（陆生的）food source and arthropods are their most abundant consumers. For this reason, plants are heavily defended by thick impervious（不可渗透的）

coverings（遮盖物）and extraordinary toxins（毒素）. However, plant fitness（适应性）also depends upon alliances（同盟）with arthropods, such as with pollinators（传粉者）. These interactions are mediated in part by an enormous diversity of plant chemical products, many of which have resulted from pressures to deter（制止）and attract other organisms. Understanding the conflicts and alliances between plants and arthropods will help plant farmers, breeders, and growers to decrease the impact of herbivorous（草食的）arthropods on crop yields without impinging（冲击）upon the beneficial arthropods.

Plants and arthropods began to live on land more than 400 million years ago. Four-hundred-million-year-old fossils are rare but reveal a fairly simple, homogeneous（均匀的）early ancestry for each group, as well as clear signs of plant herbivory by arthropods [including plant tissues in fossilized arthropod excrements（粪便）, also known as coprolites（粪化石）]. Over time, arthropods developed increasingly sophisticated（复杂的）mouthparts（口器）that enabled them to pierce and bite through tough plant material and specialized digestive systems that enabled them to use plant material as food and to neutralize dangerous plant substances.

The basic conflict between plants and animals is about food. Plants can do a trick（特技）that animals cannot, photosynthesis（光合作用）, and animals are hungry and have to eat to grow, develop, and, especially, to reproduce. Hence, about 50% of the known arthropod species (over one million) are plant eaters. However, animals can do also tricks that plants cannot do. They are mobile and often eat other arthropods. Plants and arthropods have sometimes evolved a mutualism（互利共生）(*i.e.*, an interaction in which different species become allies since they both derive a fitness benefit from interacting). Two such alliances are common in nature: (1) an alliance in which plants accommodate hungry carnivores（食肉动物）such that these liberate them from herbivores and (2) an alliance in which plants feed mobile hungry arthropods via floral nectar to establish pollination（授粉）. These alliances, however, are extremely tense since each of the participants has been selected to maximize its own fitness and not that of other organisms. Natural selection causes the genotypes of the individuals with the highest reproductive success (*i.e.*, the highest fitness) to become increasingly abundant during the consecutive generations. This implies that natural selection will be hard on groups of reproductive organisms that display forms of optimal resource management since these groups are prone to invasion by selfish genotypes that maximize rather than optimize their fitness. As a consequence, arthropod pollinators and natural enemies of herbivores were not selected to be friendly, they are in competition with other arthropods and were selected to try to get as much as they can. For this reason, flowering plants have to control the behavior of beneficial arthropods. Otherwise, these arthropods may continue eating plant tissues after the herbivores are consumed or plunder and destroy flowers during nectar feeding. Like any relationship, those between plants and arthropods can require a lot of effort to maintain.

Plant fitness is maximal when nutrient loss to herbivory is minimized, so plants are under selection to restrict herbivore feeding as cost-efficiently as possible. Plant defenses to herbivory (草食性动物) include physical and chemical deterrents (阻碍物), often toxins, and indirect defenses that entail the recruitment of predators (捕食者) and parasitoids (拟寄生物) of arthropods. These plant defenses in turn select for counteradaptations (逆向适应) in herbivorous arthropods. Plants produce constitutive defenses, which are always present, but also induce additional defenses when attacked, it is thought that this combination may provide an optimal defense strategy without unnecessary, wasteful resource expenditure.

Many herbivorous arthropods are specialist feeders (mono- or oligophagous, 寡食性的), whereas others are more generalized (polyphagous, 杂食性的). Herbivorous arthropods are dependent on plants to meet their nutritional requirements, including water, phytosterols (植物固醇), vitamins, lipids, and an appropriate ratio of protein to digestible carbohydrates. Monophagous species are highly dependent upon their host (宿主) plant. Although insects that undergo incomplete metamorphosis (不完全变态) (like scale insects, grasshoppers (草蜢), *etc.*) use similar food throughout their life, the different stages of insects that undergo complete metamorphosis (like butterflies) may require different foods. In addition, plant nutritional quality and particularly protein levels may vary depending on varying and fluctuating environmental conditions.

Arthropods eat all parts of the plant including roots, leaves, stems, flowers, pollen, seeds and fruits. They have evolved a wide variety of feeding styles, which can be broadly classified as chewing or piercing. The chewing insects have jaws (颌) and include beetles (甲虫), caterpillars (毛虫), and stem or fruit borers (钻心虫), some are leaf miners (潜叶虫) that eat the tender mesophyll (叶肉) cells within the leaf. Piercing arthropods include aphids (蚜虫) and mites (螨虫) and have needlelike (针状的) stylets (吻针) that pierce tissues and suck nutrients out from phloem, xylem (木质部), or parenchyma (薄壁细胞) tissues.

Chewing insects have salivary glands (唾液腺) that secrete saliva into the oral cavity (口腔), which comes into contact with damaged leaf tissues during chewing. Moreover, some chewing insects regurgitate (反刍) (*i. e.*, they mix the plant material with gut enzymes and then digest the mixture in the oral cavity and outside the body). By doing so, larger volumes of food can be digested while toxins are kept away from the gut until they are detoxified (被解毒). Chewing causes extensive mechanical damage to plant tissues, and often these feeding sites are entries for opportunistic pathogens. Stylet-feeding arthropods have mouthparts that during the course of evolution have been modified into needle shapes and usually comprise separate canals (通道) for saliva and food ingestion. Upon insertion of the stylets, saliva is injected into the plant tissue where it may predigest the plant tissue and interfere with local defenses. Stylet feeders usually cause only minor damage to plant tissues, although some species can be very damaging to the tissues they pass when drilling for phloem. Among the arthropod lineages (血统), piercing-sucking and chewing may have evolved more than once.

At least seven different groups of arthropods, usually stylet feeders, are able to induce galls (虫瘿) on plant tissues. Galls are localized regions of cell proliferation, and in some cases, the arthropod manipulates plant hormone levels to produce the tissue proliferation. The arthropods lay their eggs in the gall tissues, which form a shelter for the developing larvae (幼虫). Gall shape, size, and chemistry are extremely diverse. Some studies have found that the level of nutrients within the gall is high, and the level of defense compounds is low in the gall interior but high in the outer layers. In some cases, plant cells are manipulated to produce nourishment for the developing arthropods via formation of specialized feeding cells.

Plant defenses can be roughly divided in direct and indirect defenses. Direct defenses are established by the plant via morphological or chemical changes that directly affect the plant eater. Indirect defenses are morphological or chemical changes that facilitate foraging (觅食) by natural enemies of plant eaters. Interactions between plants (first trophic level) and herbivores (second trophic level) via carnivores or parasitoids (third trophic level) are also referred to as tritrophic interactions. Both direct and indirect defenses can be constitutive (always present) or induced.

Plants and plant tissues vary in their degree of defensiveness. Large, long-lived plants are often more highly defended than small, short-lived plants that may be variable in their time and place of emergence. Nutrient-rich species, or tissues such as seeds, are often more highly defended than less nutritious ones. Plants defend their resources mainly via decreasing resource palatability (适口性) as described below but also can reallocate resources to roots for storage or directly into reproductive tissues. Moreover, when infestations persist (*i. e.*, when plant defenses are inefficient), plants often initiate emergency actions, such as senescence and cell death of infested tissues to isolate the attacker from the remaining healthy tissues and to deprive it of food. Let it be noted that, despite all defenses, plants are often not fully successful in eliminating an attacker.

The plant surface provides many barriers against herbivory. The surface texture and composition of the cuticle (角质层) affects herbivores' ability to move on the plant surface; slick, slippery surfaces are more difficult to adhere to or hamper movement. Some arthropods use silk or sticky secretions (分泌物) to move about on the plant. Thorns (荆棘) are obviously obstacles but may be more effective against larger herbivores than against arthropods. Trichomes (表皮毛) (epidermal hairs) are similar to thorns but smaller and so effective as barriers against smaller animals. Some arthropods are able to avoid damage from barbed or hooked trichomes by covering these over with silk meshes (网状物) or biting off the ends. Specialized glandular (腺状的) trichomes are not only physical barriers but also produce defensive chemicals, such as fast-acting sticky substances that trap the herbivore, or toxic, repellent (驱虫物), or deterrent substances that reduce or prevent further herbivory. As examples, a damaged glandular trichome of wild potato releases terpenoid (萜类) substances identical to aphid alarm pheromones (信息素), motivating other aphids to stay away, and the sugars ingested by caterpillars on *Nicotiana attenuata* are hydrolyzed and released as volatiles (挥发物) that attract predatory (捕食性的) ants.

Approximately 10% of angiosperms (被子植物) produce latex (乳胶) or resin (树脂) or similar exudates (分泌物). Latex is usually rich in toxic chemicals and has been compared with animal venom (毒液). Among the compounds found in latex are toxic alkaloids (生物碱) (for example, morphine in poppy latex) and Cys proteases. Latex-producing plants include the rubber tree (*Hevea brasiliensis*, 巴西橡胶), poppy (*Papaver somniferum*, 罂粟), papaya (*Carica papaya*, 番木瓜), and milkweed (*Asclepias* spp., 马利筋属亚种). Latex is stored under pressure in vein-associated lactifers (产乳丝). When lactifers are bitten, latex is extruded. Arthropods that feed on latex-producing plants can avoid the latex by biting through veins, often via leaf trenching at an upstream point, causing the lactifer to empty. Downstream of the cuts, the herbivore can feed unmolested by latex. Vein cutting and trenching are behavioral countermeasures. Plants constitutively produce many antiherbivorous chemicals, but because many of these compounds, such as nicotine, are induced to accumulate more abundantly in response to herbivory.

Abstracted and adapted from *Plants and Arthropods: Friends or Foes?* by Merijn. R. Kant, Mary. Williams. The Plant Cell, 2011. *http://www.plantcell.org/cgi/doi/10.1105/tpc.111.tt0811.*

Reading Comprehension

1. What are the interactions between arthropods and plants?
2. What benefits will people harvest after realizing the conflicts and alliances between plants and arthropods?
3. How do herbivorous arthropods adapt to defense mechanism in plant?
4. How do plants defend themselves against herbivory?
5. How many feeding styles are there in arthropods?
6. What are the two alliances between plant and arthropods?
7. What is the function of galls on plant tissues?
8. What do trichomes function as when plants defend against herbivory?

Answers

1. It can be simplified into a basic conflict and two uneasy alliances.
2. To decrease the impact of herbivorous arthropods on crop yields without impinging upon the beneficial arthropods.
3. Developed increasingly sophisticated mouthparts that enabled them to pierce and bite through tough plant material and specialized digestive systems that enabled them to use plant material as food and to neutralize dangerous plant substances.
4. Plants defend against herbivory through physical and chemical, moreover, produce constitutive defenses and induce additional defenses when attacked.
5. Two, chewing and piercing.

6. Arthropods provide mobile vectors to transfer gametes from plant to plant, and plants entice and reward them through various measures.
7. Galls can form a shelter for the developing larvae of arthropods.
8. Trichomes are not only physical barriers but also produce defensive chemicals.

Lesson Two

Biological Membrane

2.1 Intensive Reading

Membrane

Membrane Composition

Cell membranes contain a variety of biological molecules, notably lipids and proteins. The cell membrane consists of three classes of amphipathic [1] lipids: phospholipids [2], glycolipids [3], and cholesterols [4]. The amount of each depends upon the type of cell, but in the majority of cases phospholipids are the most abundant. Proteins within the membrane are the key to the functioning of the overall membrane. These proteins mainly transport chemicals and information across the membrane. Every membrane has a varying degree of protein content. Proteins can be in the form of peripheral or integral. Plasma membranes also contain carbohydrates [5], predominantly glycoproteins [6], but with some glycolipids.

Membrane Structure

Membranes consist of a phospholipid bilayer combined with a variety of proteins in a fluid mosaic model [7]. The surfaces of cell membranes are hydrophilic [8] (water-loving), the interiors are hydrophobic [9]. Hydrophilic molecules tend to interact with water and with each other. Hydrophobic molecules avoid interaction with water and tend to interact with other hydrophobic molecules.

Biological membranes are thin, flexible surfaces separating cells and cell compartments from their environments. Different membranes have different properties, but all share a common architecture. Membranes are rich in phospholipids, which spontaneously form bilayer structures in water. Membrane proteins and lipids can diffuse laterally within the membrane, giving it the properties of a fluid mosaic. Membranes are asymmetric, interior and exterior faces carry different proteins and have different properties.

Membrane Function

Transport

Cells require and use energy and materials to perform cellular tasks. Such task might include movement, packaging and exporting materials, dividing and reproducing.

Materials move through membranes and within cells by passive transport mechanisms such as diffusion [10] or osmosis [11]. In passive transport, the cells do not use any energy to move the molecules. The molecules move through a gradual change or gradient. Materials may also move through membranes by active transport mechanisms. Here the cell uses energy to get molecules into or out of the cell against the gradient. Active transport is a little bit like going the wrong way on a one-way street.

Diffusion is the tendency of molecules or materials to move from areas of high concentrations into areas the same molecules are in a lower concentration. Most materials move by simple diffusion through the semi permeable membrane [12] surrounding the cell. A semi permeable membrane only allows certain types of molecules to enter or leave the cell. Limitations may be based on size or charge of the molecules.

Osmosis is the movement of a solvent such as water through a semi permeable membrane from areas of high concentration to areas of low concentration of the same solvent. In cells the solvent is water. Water moves readily across cell membranes through special protein-lined channels, and if the total concentration of all dissolved solutes is not equal on both sides, there will be net movement of water molecules into or out of the cell. Whether there is net movement of water into or out of the cell and which direction it moves depends on whether the cellular environment is isotonic [13], hypotonic [14], or hypertonic [15].

Active transport may move solutes into the cell or out of the cell, but energy is always used to move the solute against its concentration gradient. Active transport can occur as a direct result of ATP hydrolysis [16] or by coupling the movement of one substance with that of another (symport [17] or antiport [18]). Most living cells maintain internal environments that are different from their extracellular environment, as well as concentration differences between the cytosol and internal compartments. In plant tissues, for example, all cells have a higher concentration of Na^+ outside the cell than inside, and a higher concentration of K^+ inside the cell than outside. These concentration gradients of Na^+ and K^+ represent a form of energy storage, similar to a battery.

Endocytosis [19] is the movement of materials into a cell via membranous vesicles. Exocytosis [20] is the movement of materials out of a cell via membranous vesicles. These processes allow patches of membrane to flow from compartment to compartment, and require us to think of a cell as a dynamic, rather than static, structure. In endocytosis, membranes invaginate, or pinch in, to form a vesicle, moving the enclosed materials inside the cell. Exocytosis is the movement of intracellular vesicles to the plasma membrane, where they fuse with the membrane and release their contents into the surrounding fluid.

Transmembrane Signaling

Membranes have surface receptors [21] that recognize signaling molecules such as peptide hormones [22]. Binding of the signal activates other proteins to cause specific responses inside the cell, a process called signal transduction. One of the common types of signal transduction is mediated by a class of proteins called G-proteins.

G-proteins can bind GTP (guanosine [23] triphosphate) when stimulated by hormone binding to a receptor protein. The activated G-protein then passes a phosphate group to an inactive enzyme. The newly phosphorylated[24] enzyme changes shape to become active, and catalyzes many enzymatic reactions.

In summary, the fluid mosaic membrane model appears to resemble a flexible, undulating lipid layer with randomly positioned protein molecules extending partially or completely through the bilayer. Most biologically important organic molecules are insoluble in the center of the bilayer and thus the barrier properties of the membrane. To pass through this nearly impermeable barrier, many compounds require the aid of ATP and a protein molecule acting in some role as a carrier.

Abstracted and adapted from *Membranes from Polymerizable Lipids* by Han Zhang, James R. Joubert , S. Scott Saavedra. Advances in Polymer Science, 2010, 224:1-42. *http://www.biology.arizona.edu/cell_bio/problem_sets/membranes/index.html.*

Notes

[1]amphipathic（双亲分子的）: of or related to a molecule that possesses both hydrophobic and hydrophilic groups.

[2]phospholipid（磷脂）: any lipid that containing phosphate.

[3]glycolipid（糖脂）: any lipid containing carbohydrate groups.

[4]cholesterol（胆固醇）: a sterol found in all animal tissues, blood, bile, and animal fats; a precursor of other body steroids.

[5]carbohydrate（碳水化合物）: polyhydroxyl aldehydes and / or ketones and their derivatives, so named because they have a general formula of $(CH_2O)_n$.

[6]glycoprotein（糖蛋白）: a conjugated protein covalently linked to one or more carbohydrate groups.

[7]fluid mosaic model（流动镶嵌模型）: a model used to conceptualise membrane structure, which states that the basic structure of the membrane is a fluid lipid bilayer embedded with various proteins.

[8]hydrophilic（亲水的）: having strong affinity for water.

[9]hydrophobic（疏水的）: lacking affinity for water, tending to repel or not to absorb water.

[10]diffusion（扩散）: the nonenergy driving spontaneous movement of molecules or particles.

[11]osmosis（渗透）: diffusion of fluid through a selective permeable membrane until there is an equal concentration of fluid on both sides of the membrane.

[12]semi permeable membrane（半透膜）: a membrane that prevents the passage of some substances while allows the passage of others.

[13]isotonic（等渗的）: having the same osmotic pressure as another solution.

[14]hypotonic（低渗的）: having a lower osmotic pressure than a reference solution.

[15]hypertonic（高渗的）: having a higher osmotic pressure than a reference solution.

[16]hydrolysis(水解): decomposition of a compound by reaction with water.

[17]symport(同向运输): a mechanism of transporting two compounds simultaneously via the same transporting protein in the same direction.

[18]antiport(反向运输): a mechanism of transporting two compounds simultaneously via the same transporting protein in opposite direction.

[19]endocytosis(内吞作用): the uptake of material into a cell by the formation of a membrane bound vesicle.

[20]exocytosis(胞吐作用): release of material from the cell by fusion of a membrane bounded vesicle with the plasma membrane.

[21]receptor(受体): a molecule on the surface or within a cell that recognizes and binds to specific molecules, producing a specific signal inside the cell.

[22]hormone(激素): a regulatory substance produced in the cells which has specific effect on target cells.

[23]guanosine(鸟嘌呤核苷): a purine nucleoside, guanine linked to ribose.

[24]phosphorylate(使磷酸化): to introduce a phosphate group into an organic molecule.

Reading Comprehension

Ⅰ Answer the Following Questions Based on the Information Given in the Text

1. Describe the structure and function of the membrane.
2. Describe and give examples of the cell processes of: diffusion, osmosis, active transport, endocytosis and exocytosis.

Ⅱ Completion

1. Membranes consist of a phospholipid ________ combined with a variety of proteins in a ________ model.
2. The membrane protein components of biological membranes are of two types: ________ and ________ proteins.
3. Most biologically important solutes require protein carriers to cross cell membranes, by a process of either ________ or ________ transport.
4. ________ (movement of water across membranes) depends on the relative concentration of solute molecules on either side of the membrane.
5. In contrast to facilitated diffusion(易化扩散), active transport requires the use of ________ by a carrier protein in order to move ions or molecules across the ________ against a concentration gradient.

Answers

Ⅰ Answer the Following Questions Based on the Information Given in the Text

1. Cell membrane is composed of a phospholipid bilayer with protein molecules embedded in them. It separates the cell from the surrounding environment and controls the movement of materials into and out of the cell.

2. Diffusion is the movement of molecules or particles from an area of greater concentration to an area of lesser concentration. Diffusion occurs simply because the molecules are in constant random motion.

Osmosis is the diffusion of water across a semipermeable membrane from a region of high concentration of water to a region of low concentration of water. It is simply the diffusion of water. This takes place because water molecules are very small and are constantly in motion.

Active transport is the process that takes place when movement of materials across a cell membrane requires the expenditure of cellular energy. This usually involves the movement of materials against a concentration gradient, that is, from a low concentration of that particular material to a high concentration of that particular material.

Endocytosis is active transport that brings material into the cell.

Exocytosis is active transport that takes material out of the cell.

Ⅱ Completion

1. bilayer, fluid mosaic 2. peripheral, integral 3. passive, active
4. Osmosis 5. ATP energy, membrane

2.2 Extensive Reading

Across Membrane Transport Mechanisms

Living cells need energy and materials to perform cellular tasks such as movement, transport, dividing and reproducing. Materials move through membranes and within cells by passive transport（被动运输）mechanisms or active transport（主动运输）. In passive transport such as diffusion or osmosis, the molecules move through a gradual change or gradient, and no energy is used. While in active transport, cell use energy to move materials through membranes against the gradient.

Diffusion is the tendency of molecules or materials to move from areas of high concentrations into areas the same molecules are in a lower concentration, usually through the semi permeable membrane surrounding the cell. Osmosis is the movement of a solvent such as water through a semipermeable membrane from areas of high concentration to areas of low concentration of the same solvent.

In hypotonic solutions, water moves into the cell. In isotonic solutions, the water entering and leaving is about equal and so there is no net movement. In hypertonic solutions, water moves out of a cell. Plant cells have higher solute concentrations (and thus lower solvent concentrations) than the surrounding fluids. This leads to a movement of solvent (water) molecules into the cell and causes an increase in the pressure inside of the cell. This pressure is called turgor pressure and helps to keep the cells rigid or stiff.

In facilitated diffusion, transport proteins in the membrane help move molecules down the concentration gradient without any additional energy input by the cell.